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PENSOFT

First record of the sea slug *Stylocheilus striatus* (Quoy & Gaimard, 1825) (Anaspidea, Aplysiidae) and swarming behavior for Bazaruto Archipelago, Mozambique with the first record of *Pleurobranchus forskalii* Rüppel & Leuckart, 1828 (Nudipleura, Pleurobranchidae) for Bazaruto Island (Gastropoda, Heterobranchia)

Adrienne Jochum,[1] Adrien Favre[2,3]

1 Naturhistorisches Museum der Burgergemeinde Bern, Bernastr. 15, CH-3005 Bern, Switzerland and University of Bern, Institute of Ecology and Evolution, Baltzerstr. 6, CH-3012 Bern, Switzerland. **2** Department of Molecular Evolution and Plant Systematics & Herbarium (LZ), Institute of Biology, Leipzig University, Johannisallee 21–23, D-04103 Leipzig, Germany. **3** Institute of Ecology, Evolution and Diversity, Goethe-University, Max-von-Laue-Str. 13, D-60439 Frankfurt am Main, Germany.
Corresponding author: Adrienne Jochum, adrienne.jochum@gmail.com

Abstract
Two heterobranch species, *Stylocheilus striatus* (Quoy & Gaimard, 1825) (Anaspidea, Aplysiidae) and *Pleurobranchus forskalii* Rüppel & Leuckart, 1828 (Nudipleura, Pleurobranchidae) are reported for the first time for Bazaruto Island, Mozambique. Swarming behavior of *Stylocheilus striatus*, which was previously described for other localities, was also observed for the first time in the Bazaruto Archipelago. The sea slugs were photographed *in situ* and identified in sync with their species descriptions, photographic databases and the current literature.

Key words
Mollusca; Opistobranchia; East Africa; Anantara Resort; Western Indian Ocean; Inhambane Province.

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Introduction

Marine heterobranch gastropods from the West Indian Ocean (WIO) have been the focus of recent systematic investigations, with increasing tendency towards species discoveries (Gosliner et al. 2008, Yonow 2012, Tibiriçá 2013, Goodheart et al. 2015, Tibiriçá and Malaquias 2016). This is not surprising considering that the WIO region, frequently defined with the Eastern African Marine Ecoregion (EAME) (WWF 2004), borders 4,600 km of coastline and comprises diverse ecosystems from southern Somalia to the Cape of South Africa (Everett et al. 2008, Pereira et al. 2014, van der Elst and Everett 2015). The coastline of Mozambique alone covers 2,400 km, encompassing major island and coastal habitats, including sandy and rocky shorelines, mangroves, swamps, seagrass beds, rocky reefs and coral reefs teaming with rich marine diversity (Pereira et al. 2014, Tibiriçá and Malaquias 2016).

Recently, two new species records were found on

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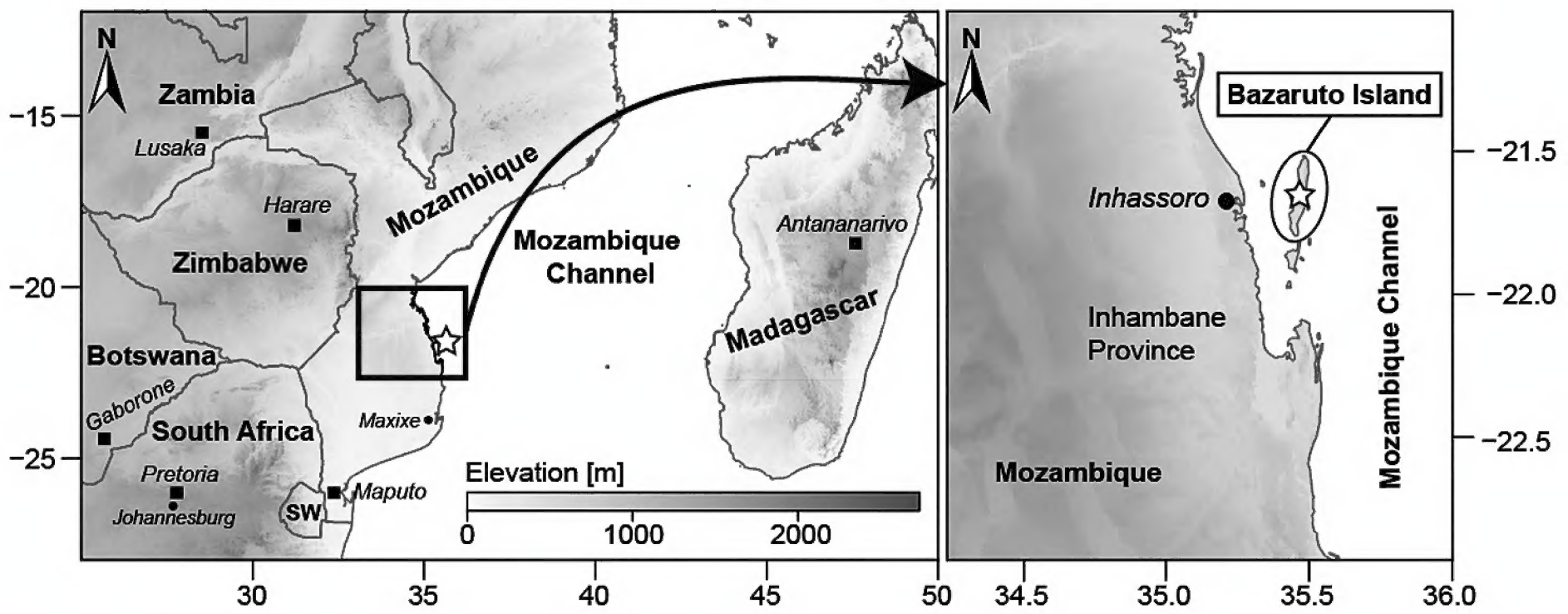


Figure 1. Map of Bazaruto Archipelago and Bazaruto Island in context of the 5 barrier islands located 20 km off the coast of Mozambique. Heterobranch observation site designated by a star.

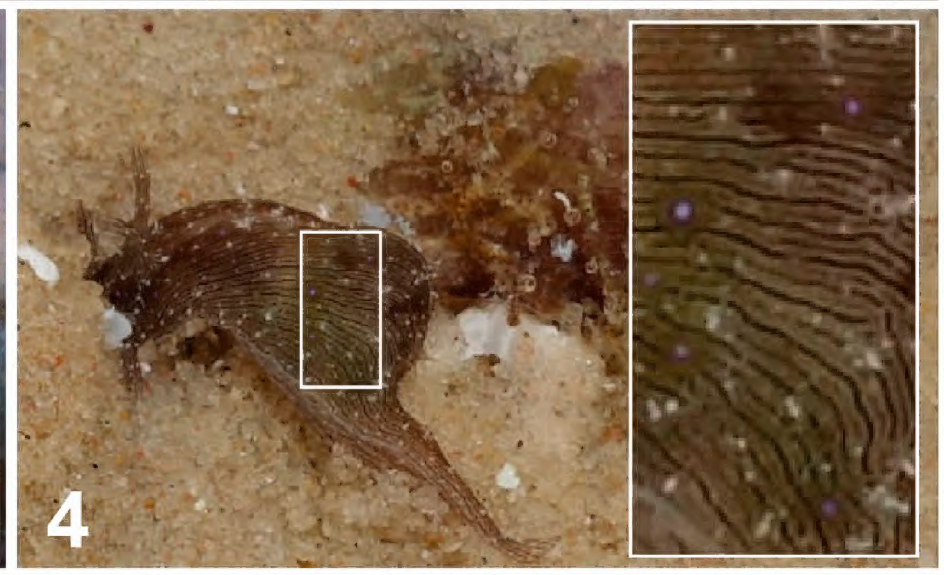
Bazaruto Island, Mozambique (Fig. 1): *Stylocheilus striatus* (Quoy & Gaimard, 1825) and *Pleurobranchus forskalii* Rüppel & Leuckart, 1828. Bazaruto is one of 5 barrier islands of the Bazaruto Archipelago, located 20 km off the Mozambique coast (Fig. 2). The aplysiid *Stylocheilus striatus* (Figs 3–11) was abundantly swarming, covering the beach in a spread of gelatinous squishy slugs. This observation constitutes the first record of *S. striatus* swarming behavior from Bazaruto Archipelago. In addition, a single nudipleurid *Pleurobranchus forskalii* Rüppel & Leuckart, 1828 (Fig. 12) was encountered at approximately the same time on a sand flat 3–4 km further south of the *S. striatus* site. This sighting represents the first record of *P. forskalii* on Bazaruto Island and the second record from Bazaruto Archipelago. The first finding was a turned over beach specimen conspicuously exposing its large gill on Benguerra Island in August 2004 (Rutherford 2005).

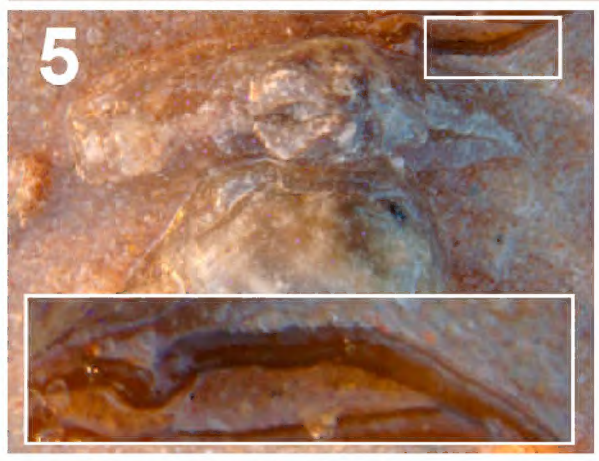
Stylocheilus striatus, or Lined Sea Hare, shows a circumtropical and circumsubtropical distribution in the Indo-West Pacific and Atlantic Oceans. Records for the West Indian Ocean include Zanzibar, Reunion Island, Mayotte Island, Mauritius, Seychelles and Madagascar (Sainte Marie Island) (Bebbington 1974, Yonow 2012). Its South African distribution extends from Mngazana in the Eastern Cape to southern Mozambique (Gosliner 1987, Perissinotto et al. 2014). All these sites are further than 575 km from Bazaruto Island, with the closest sighting reported from Inhaca Island, Mozambique (Macnae and Kalk 1962). The biggest distance between Bazaruto Island and these locations is ca 2829 km to the Seychelles. According to the IUCN Red List Categories and Criteria (2012), this species is not threatened and can be considered of Least Concern (LC).

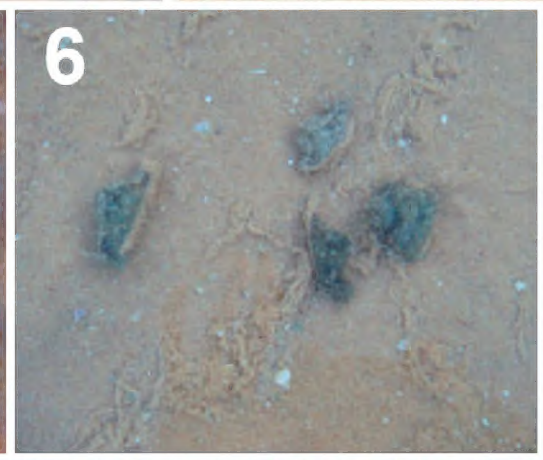
Pleurobranchus forskalii, known as Forskal's Sidegill Slug, inhabits temperate shallow subtidal areas throughout the tropical Indo-West Pacific, the Mediterranean Sea and the Red Sea (Gosliner et al. 2008, Wakimoto and Abe 2013). East African records include Tanzania (Rudman 1999a), Mauritius, Reunion, Mayotte Island, Rodrigues Island, Madagascar (Bidgrain 2010) and South Africa (Rudman 1999b). According to the IUCN Red List Categories and Criteria (2012), this species is not threatened and can be considered of Least Concern (LC).

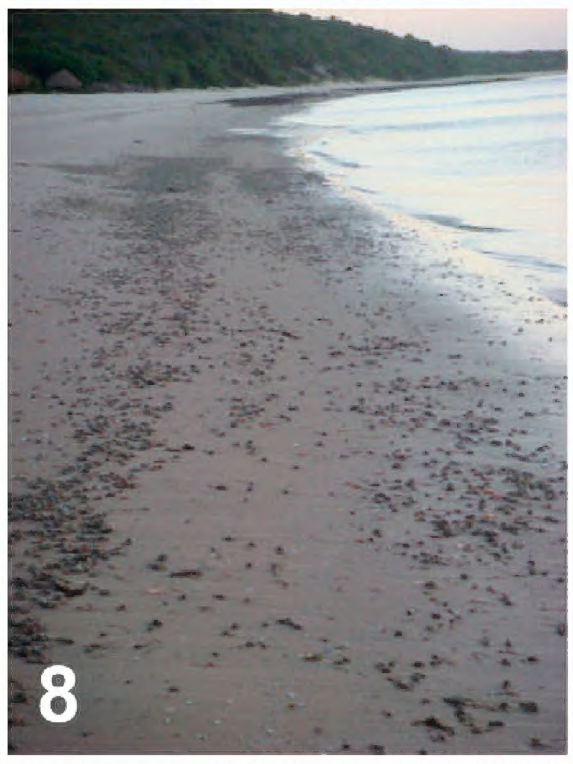
Heterobranchs are scarcely represented in the natural history literature of Mozambique and no specific account was available until recently (Tibiriçá and Malaquias 2016). Accounts from Mozambique were either reported in general faunistic reports (Bergh 1900, Macnae and Kalk 1958, 1962), phylogenetic studies of certain genera (Malaquias and Reid 2008, Price et al. 2011, Carmona et al. 2014) or in field guides presenting broader geographic realms (Branch et al 2008, Gosliner et al. 2008, King and Fraser 2014). Accounts for Bazaruto Archipelago amount to three: "Aplysia" Linnaeus, 1767 on Bazaruto Island (Helgason 2015), *Bulla ampulla* Linnaeus, 1758 on Bazaruto Island (Malaquias and Reid 2008) and *Pleurobranchus forskalii* on Benguerra Island (Rutherford 2005).

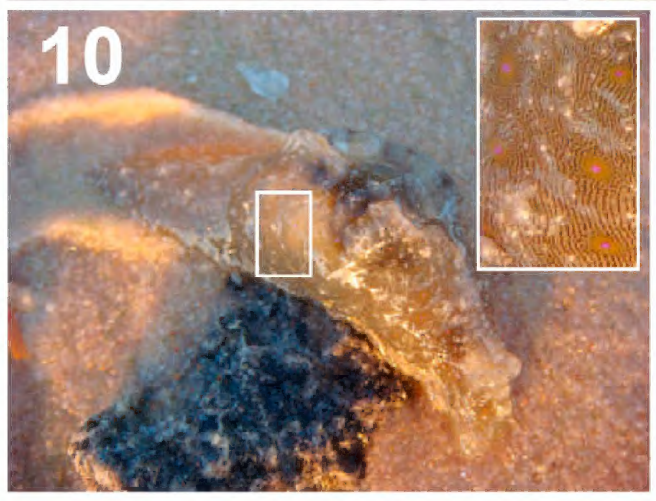
The nearest locality of a joint record, albeit sketchy, for *S. striatus* and *P. forskalii* was from Inhaca Island, Mozambique (Macnae and Kalk 1962). This site is located ca 575 km southwest of Bazaruto Island. Macnae and Kalk (1962) reported seventeen species of heterobranchs on Inhaca Island, which they described as "usually present in small numbers but which may on occasion be common". Rudman (1999b) reports these instances as occurrences "depending on the vagaries of the currents and water temperature." *Stylocheilus longicaudus* (Quoy & Gaimard, 1825), *Pleurobranchus* sp. nov. and *Pleurobranchus* sp. were identified amongst these seventeen species (Macnae and Kalk 1962). Macnae and Kalk (1962) may have described *S. striatus* instead of *S. longicaudus* when they referred to seeing "the little purple spotted sea hare crawl around, actively feeding, copulating and laying eggs." In context to these records, the aim of this paper is to provide this data for faunal inventories (i.e. IUCN, WoRMS) as well as to express a voice of confidence for continued support of conservation initiatives for the Bazaruto Archipelago and for Mozambique in general.











Figures 2–11. *Stylocheilus striatus* (Quoy & Gaimard, 1825) and swarming behavior. **2.** Western side of Bazaruto Island. **3.** *S. striatus* with parapodial lobes enclosing the large gill and anal siphon; compound and branched papillae are visible. **4.** Close-up view of dark longitudinal lines. **5.** Close-up view of amber-coloured egg strands. **6, 7.** Dense conglomerations of slime and sea slugs in the surf. **8, 9.** Aggregations of *S. striatus* on the beach and washed in between rocks at low tide. **10.** Close-up view of ocelli consisting of a pink center surrounded by an orange-brown rim. **11.** Distressed *S. striatus* exuding purplish ink.

Methods

In reference to the National Park status of Bazaruto Island, live material was not collected. The material examined was photographed and filmed *in situ* CAT (20 October at 18:24–18:40 h; 22 October at 10:34–10:36 h and 25 October at 12:29 h) using a Sony DSC−T100 digital pocket camera. Maps were created using Worldclim data (Hijmans et al. 2005) and political borders were retrieved from Esri Data and Maps (2002).

Stylocheilus striatus (Quoy & Gaimard, 1825) aggregations were imaged as they washed in the littoral and intertidal zones of shoreline located on the west side of Bazaruto Island, adjacent to the Anantara Bazaruto Island Resort and Spa (21.7067° S, 035.4468° W; Fig. 1).

The individual *Pleurobranchus forskalii* Rüppel & Leuckart, 1828 (Fig. 12) was imaged on a sand flat in the shallow intertidal zone ca 3–4 km south of the Anantara Bazaruto Resort and Spa (25 October at 12:59 h).

Figure 12. *Pleurobranchus forskalii* Rüppel & Leuckart, 1828, dorsal view.

Identification

For the first record regarding *S. striatus* here, dense aggregations of *S. striatus* littered the beach and intertidal zone as far as the eye could see (Fig. 2). Countless individuals of different sizes of *S. striatus* drifted in a mass swarming and mortality event on the western side of Bazaruto Island during 20–25 October 2014. These temporarily gregarious Blue-Ring Sea Hares were occasionally seen with an irregular tangle of amber-coloured egg strands and dense conglomerations of slime at low tide (Figs 5, 6). The former resident activities coordinator, Nicole Helgason (pers. comm.) of the Anantara Resort also observed these same aggregations, during mid-October 2014 and subsequently entered these findings as "*Aplysia*" on iNaturalist.org (7 November 2015). Though not very clear, N. Helgason's original image and description regarding this sighting still documents the same morphs of *S. striatus* bearing fine longitudinal brown lines and ocellar spots for the same day. Our observations were corroborated at the time on 20 October 2014 (pers. comm.). Identification to the genus level was confirmed by Dr. Heike Wägele (pers. comm.) on 4 November 2014. Subsequent comparisons with photographic databases and the literature enabled further identification to the species level (Rudman 1999c, d, 2001; Sachithananadam et al. 2011, Yonow 2012).

Quoy and Gaimard first described *Stylocheilus longicauda* (Quoy & Gaimard, 1825) and a second species, *Stylocheilus striatus* (Quoy & Gaimard, 1832), remarking that these two morphospecies were probably the same species. Quoy and Gaimard's (1825) description for *S. longicauda* has this species showing a uniform yellow or greenish colour and sparse, generally unbranched papillae. In sync with its name, the "tail" is long and reaches half its body length while that of *S. striatus* is short (Rudman 1999d, 2001). This morphospecies is usually referred to as *S. longicauda* or *S. longicaudus* in earlier reports (Marcus and Marcus 1970, Bebbington 1974, Rudman 1999c, d, 2001). However, the current consensus is that the name, *S. longicauda,* was used incorrectly for the common species, *S. striatus* (Rudman 1999c, d, 2001) and that earlier reports of *S. striatus* are questionable (Marcus and Marcus 1970, Bebbington 1974, Rudman 1999c, d, e, 2001). Nomenclaturally, this case has opened a "can of worms" (Willan 2000, Yonow 2012) beyond the scope of this paper and one that future phylogenetic research should definitely take on. Recent works consider two forms based on ecology and external morphological appearance (Rudman 1999d, 2001, Sachithananadam et al. 2011, Yonow 2012). *Stylocheilus longicauda* is the yellow pelagic form and drifts on floating seaweeds and other floating material (Rudman 1999d, 2001, Yonow 2012). Its long tail is likely used to grasp onto flotsam in the open ocean (Rudman 2005). *Stylocheilus striatus*, known also as the Blue-Ring Sea Hare, is the shorter-"tailed" and brown-lined, shallow water, benthic form (Figs 3−11). *Stylocheilus striatus* has dark longitudinal lines, a translucent body, compound to several branched papillae and shows a mottled color pattern with ocelli consisting of a blue or pink center encircled by an orange-brown rim (Rudman 1999d, 2001, Sachithananadam et al. 2011, see Figs 4, 10). Like many aplysiid sea hares, purple ink is exuded when disturbed (Fig. 11).

Adult *Pleurobranchus forskalii* is usually dark plum red although it can be found in shades of peach, to dark orange to dark purple (Bidgrain 2010). Color ranges known for *P. forskalii* include dark brown to a lighter brown variation with dark brown rings (Fig. 12), pale brown with black rings, brownish with white rings, red with white rings, and dark brown with white ornaments to complete red (Köhler 2016). The conspicuous opaque white arches or "semicircles" outlining clusters of pustules characterize these slugs. The individual encountered on Bazaruto Island (Fig. 12) was not crawling and thus, did not reveal the characteristic tubular siphon at the posterior end of the mantle, which is used for channeling water and excreting feces (Bidgrain 2010).

Pleurobranchus forskalii is similar to *P. albiguttatus*,

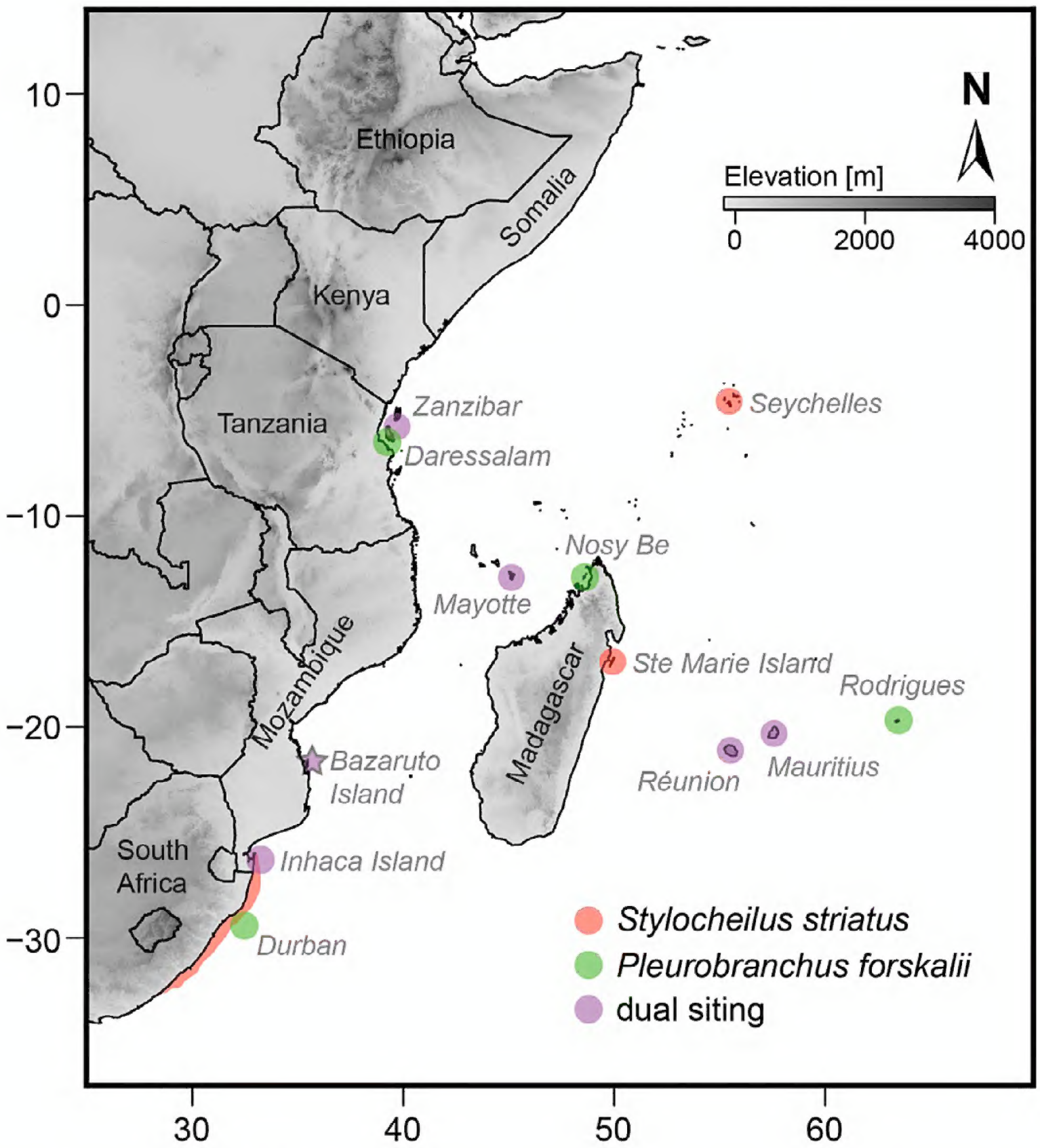


Figure 13. Map of recorded sightings of *Stylocheilus striatus* (Quoy & Gaimard, 1825) and *Pleurobranchus forskalii* Rüppel & Leuckart, 1828 in the West Indian Ocean.

P. grandis, *P. mamillatus* and *P. peroni*, but is clearly distinguishable by the dark brown rings known for the lighter form and the white semicircles on the mantle (Bidgrain 2010).

Discussion

The observed mass-swarming phenomenon is not uncommon for *S. striatus* within its circumtropical range (Apte 2009, Bidgrain 2005, de Vargas Ribeiro et al. 2017), and has been reported for other tropical heterobranch species as well (Rudman 2001, Perissinotto et al. 2014). It is known to be locally common in sea grass beds and shallow water, particularly during mating season (Yonow 2012, Bidgrain 2005). It is likely that this event coincided with a period of very hot weather. These swarming occurrences likely reflect very favorable conditions, when large numbers of juveniles settle out of the plankton and grow rapidly to maturity (Rudman 2001). Subsequently, they synchronously die together.

Yonow (2012) conducted an extensive study of 70 species of Heterobranchia from the Western Indian Ocean, including the aforementioned known distributions of *S. striatus* and *P. forskalii* in this region. The map (Fig. 1, Yonow 2012) shows the western half of the Indian Ocean, whereby the coast of Mozambique was still devoid of Heterobranchia. *Stylocheilus striatus* from Zanzibar was included in this study, while *Pleurobranchus forskalii* was not. Yonow (2012) emphasized the need for a revision of the genus *Stylocheilus* encompassing a comparison of specimens from different regions and habitats as well as a comprehensive review of the literature. We couldn't agree more.

The World Register of Marine Species (WoRMS 2016) reports 431 species of molluscs for Mozambique. Forty-seven of these belong to the Heterobranchia. This number reflects a great underestimation for Mozambique especially since recent studies presenting the diversity of nudipleuran sea slugs collected in this country revealed that 170 species were recorded within a radius of 20 km

of coastline (Tibiriçá 2013, Pereira et al. 2014). Tibiriçá and Malaquias' (2016) seminal studies presented 80% of the new records for Mozambique, indicating 36 potentially new species.

Marine ecosystems are still incompletely inventoried with new species continuing to be described at a pace of ca 1800 species per year (Bouchet et al. 2002). The tropics harbor approximately 75% of newly described marine molluscs for which 43% alone were recorded for the Indo Pacific two decades ago (Bouchet 1997). For heterobranchs, 30% of 3400 Indo-Pacific species were undescribed twenty years ago (Gosliner and Draheim 1996). Meanwhile, a plethora of new species and distributions have been described since then, for which the Indo-Pacific coastal realm continues to lead in terms of global numbers (Bouchet et al. 2002, Tibiriçá and Malaquias 2016). Currently Mozambique, like most of Africa, is not yet available on the IUCN Red List radar; it is, however, considered "A focal point for national red lists and species action plans" (IUCN 2012).

These two reports from Bazaruto Island add new species data for East African occurrences and extend the range of *S. striatus* and *P. forskalii* from southern Mozambique (Inhaca Island) 575 km northwards in the Mozambique Channel as well as 1,406 km south from Mayotte Island, their northernmost distribution in the Mozambique Channel (Fig. 13). This report corroborates as well as augments the knowledge of individual forms, color patterns and the context dependent behavior of these two heterobranch species in the Bazaruto Archipelago during mid-October 2014.

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Authors' Contributions

AJ wrote the first draft of the manuscript, and both authors contributed to writing the final version. AF compiled the maps and figures.

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